PUMP CONTROL SYSTEM

The present invention relates generally to a pump control system. In particular the present invention relates to a sensor assembly for a pump control system.

A simple pump controller for controlling an irrigation, industrial or domestic water pump typically employs a pressure switch which is set to operate the pump between low and high pressure thresholds. The switch turns the pump on when the low threshold is reached and off when the high threshold is reached.

One deficiency of such a controller is that the pump tends to cycle unnecessarily between the two thresholds. When a centrifugal pump is used, for example, it would be much more desirable to operate the pump continuously until the associated outlet is turned off, since running the pump at maximum pressure is not an issue.

To achieve this, flow detection has been introduced in some prior art pump controllers in addition to pressure detection. This allows the pump to turn off in the absence of flow but adds considerable complexity to the pump controller and has been achieved with sensors fundamentally different in form. Moreover, such sensors tend to have operating points that need to be manually adjusted in the field to match the output of the pump to the requirements of an installation site. In a stand alone installation (ie. an installation to an existing pump system)

it is desirable that the pump controller automatically adapts to any viable combination of installation and pump.

Attempts have been made to address the above problems with relatively simple adaptive systems but the known solutions still all interrupt the pump causing an undesirable decline in pressure. One solution involves measuring the performance of the pump by monitoring closed head pressure. The controller may determine that pressure is required when a predetermined drop in pressure (eg. 20%) is detected and may start the pump in response to such drop in pressure.

The present invention addresses the problem by means of an integrated sensor system mounted to a metal substrate that is in direct contact with the flow of water or other pumped fluid or medium. The metal substrate preferably includes a titanium plate. In some embodiments the substrate may include low carbon stainless steel. The sensor system includes pressure sensing means such as a strain gauge. The strain gauge preferably includes a thick film piezo resistor mounted directly onto the dry side of the metal substrate. The sensor system includes flow sensing means utilising thermal transfer or loss measurement techniques. Flow sensing means based on thermal techniques are described in publicly available documents including WO91/19170 entitled "Flow Sensor and Control System", the disclosure of which is incorporated herein by cross reference. The flow sensing means includes a source of heat such as a heater element and a plurality of temperature sensors such as thermisters.

The heater element and the or each thermister may be printed directly onto the dry side of the metal substrate utilising thick film technology. A control unit for controlling thresholds and operation of the system may be mounted in close proximity to the pressure/flow sensing means such as directly onto the metal substrate.

The control unit may include a microprocessor or microcontroller. The control unit may have its inputs connected to the pressure sensing means and / or the flow sensing means via conductive tracks printed directly onto the dry side of the metal substrate. The metal substrate includes on its dry side, an insulator such as a ceramic to insulate the conductive tracks and other components from the metal substrate.

Construction of the sensor system onto a common metal substrate facilitates dissipation of heat, typically from the pump switching element such as a triac. In some embodiments the triac may also serve as the source of heat for the flow sensing means, dispensing with the need for a separate heater element.

Construction of sensing elements onto a metal body utilising thick film technology involving printing and firing of dielectric inks is described in publicly available documents including US5867886 entitled "Method of making a Thick Film Pressure Sensor" and US6022756 entitled "Metal Diaphragm Sensor with Polysilicon Sensing Elements and Methods therefor", the disclosures of which are incorporated herein by cross reference.

A desirable feature of a sensor assembly for a pump controller is that the assembly functions reliably notwithstanding that it is required to interface directly with the pumped fluid medium under pressure. The pumped medium may present an inherently hostile environment to sensitive electronic components. The sensor assembly may be effectively isolated from the hostile environment due to its placement on the dry side of the sensor substrate. However, it is still necessary to ensure that the dry side of the substrate is effectively sealed against ingress of moisture from the wet side. The means used for sealing the sensor assembly preferably is effective in an environment in which fluid pressure causes the sensor substrate to deflect. Controlled deflection is a desirable feature of the sensor substrate as this may transmit information about the pressure of the fluid to the pressure sensing means on the dry side of the substrate. The sealing preferably also should be achieved relatively economically for a mass produced sensor assembly.

The sealing means may include at least a first seal element and a second seal element. The first seal element may include an elastomeric material such as a natural or synthetic rubber. The first seal element may be adapted to substantially prevent ingress of fluid under relatively high pressure of the pumped fluid medium. The first seal element may surround an opening in a sensor housing which communicates with the pumped medium. The first seal element may include a peripheral bead. The first seal element may be interposed between the wet side of the substrate body and a peripheral portion of the housing surrounding the opening in the housing. The elastomeric

material may be chemically inert with respect to the pumped medium. The elastomeric material may be at least sufficiently resilient to allow the substrate body to deflect incrementally whilst minimising ingress of pumped medium into the housing. Because some ingress of medium may be unavoidable, the first seal element may include a leak path to a first chamber. The first chamber may be vented to atmospheric pressure. The first chamber may be isolated from the dry side of the substrate body by means including a second seal element. Venting of the first chamber to the atmosphere may ensure that any high pressure leak drains to the atmosphere before it penetrates the second seal element which protects the dry side of the substrate body.

The second seal element may include an elastomeric material such as natural or synthetic rubber. The second seal element may include a peripheral bead. The second seal element may be interposed between a peripheral edge associated with the first chamber and a closure element. The closure element may include a second chamber. The second chamber may be vented to atmospheric pressure. The second seal element may be adapted to substantially prevent ingress of moisture to the second chamber. The second seal element may include a resilient wall which can respond to changes in internal pressure caused by atmospheric conditions or changes in temperature. The resilient wall may substantially prevent ingress of damp air (moisture) over time. The second chamber may be in communication with the dry side of the sensor substrate. The second chamber may be adapted to house electronic components associated with the sensor system.

The first and second seal elements may be interconnected. The seal elements may be connected by means of a membrane. The membrane may be formed from the same or similar material as the first and second seal elements or it may be formed from dissimilar material. The membrane may be formed integrally with the seal elements. The membrane may be shaped to envelop at least the peripheral edge of the substrate body. The sensor housing and associated closure may include one or more recesses adapted for receiving the first seal element, the second seal element and the enveloped peripheral edge of the substrate body.

The housing including the sensor assembly may be interposed upstream or downstream relative to the pump.

The sensor housing may include a venturi device designed to accelerate the flow of the pumped medium at least in the vicinity of the wet side of the substrate body. The venturi device may include a formation utilising the venturi principle to convert pressure energy associated with flow of the pumped medium to kinetic energy, through a narrowed portion of the formation. The venturi device may be located in the vicinity of an outlet in the sensing housing and may be adjacent the opening in the housing which facilitates communication of the pumped medium with the wet side of the substrate body.

According to one aspect of the present invention there is provided a pump controller for controlling a pump for a fluid medium such as water, said pump controller including:

a metal substrate adapted to have a first side thereof exposed to said fluid medium;

an insulating medium applied to a second side of said substrate;

pressure sensing means including at least one pressure responsive element implemented on said insulating medium closely adjacent said substrate such that said pressure element is responsive to pressure of said fluid medium when said first side is exposed to said fluid medium;

flow sensing means including at least one source of heat and at least one temperature responsive element implemented on said insulating medium closely adjacent said substrate, such that said temperature responsive element is responsive to flow of said fluid medium when said first side is exposed to said flow, said fluid medium providing a sink for said source of heat in a manner that is related to said flow;

switching means for switching said pump on or off; and

processing means for receiving data from said pressure sensing means and said flow sensing means, said data being communicated via conductive tracks implemented on said insulating medium, said processing means being adapted for processing said data and for producing an output for driving said switching means.

According to a further aspect of the present invention there is provided a housing for a sensor substrate having a wet side and a dry side and adapted to promote contact of said wet side with a fluid medium and to substantially prevent contact of said dry side with said fluid medium, said housing including:

a main body having an opening for said fluid medium and for receiving said sensor substrate with its wet side exposed to said opening;

a first chamber maintained substantially at atmospheric pressure;

first sealing means arranged between said opening and said sensor substrate such that a leak path is provided to said first chamber;

a closure for said housing including a second chamber exposed to said dry side of said sensor substrate; and

second sealing means arranged between said closure and said first chamber to substantially prevent ingress of said fluid medium to said second chamber.

To minimize cycling of the pump controller in the face of small leaks or drips (in a non resilient hydraulic circuit a small drip can cause the pressure to drop significantly) which could trigger an undesirable number of short runs of the pump, it is highly desirable to provide a leak compensating device such as an accumulator. The accumulator may be spring powered and may compensate a minimum quantity (eg. 30 cc.) of drawn off water or the like. The accumulator may be external or it may be integral with the pump controller.

Alternatively or additionally the processing means may be programmed via suitable software adapted to detect small leaks such as a dripping tap. In one form the software may interpret a sequence of pump running cycles of substantially the same or regular duration as a 'slow leak'. This may switch the pump to a 'dripping tap mode' wherein the predetermined drop in pressure which causes the pump to start may be increased from, say 20% to 50%. The greater reduction in pressure may also cause the leak to self heal in some

instances, avoiding further running of the pump. This may increase the time between pump running cycles. The 'dripping tap mode' may be implemented for a set period, say 2 days, before switching the pump back to its standard operating mode. The software may additionally include a 'cistern fill mode'. The 'cistern fill mode' may be implemented if a sequence of short pump running cycles is detected in quick succession, say 3 running cycles in 45 seconds. In the 'cistern fill mode' the pump may be run continuously for say 2 to 4 minutes. The continuous runs of the pump may be repeated until the short pump running cycles are no longer detected.

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings wherein:

Fig. 1 shows an overview of the sensor system mounted to a sensor substrate;

Fig. 2 shows functional elements associated with the pressure and flow sensing means;

Fig. 3 shows a schematic circuit diagram of electronics associated with the sensor system;

Fig. 4 is a cross section through the sensor housing showing a double seal protecting the dry side of the sensor substrate from high pressure fluid;

Fig. 5 shows the wet side of the sensor substrate mounted within a seal assembly;

Fig. 6 shows the dry side of the sensor substrate mounted within the seal assembly;

Fig. 7 shows a similar view to Fig. 6 with electronic components mounted to the dry side of the sensor substrate;

Fig. 8 shows the main body of the sensor housing for the sensor assembly with its closure member;

Fig. 9 shows the underside of the closure member;

Fig. 10 shows the flow-sensing opening in the main housing which facilitates communication of the pumped fluid with the wet side of the sensor substrate;

Fig. 11 shows the sensor assembly of Fig. 6 fitted to the main housing; and

Fig. 12 shows a venturi device adjacent the flow sensing opening.

Fig. 1 shows one form of sensor assembly 10 according to the present invention. The sensor assembly 10 includes a substrate 11 in the form of a titanium or alternatively a stainless steel plate. Substrate 11 includes pressure sensing means 12 and flow sensing means 13 implemented directly onto its dry

side using thick film hybrid technology. Pressure sensing means 12 contains four pressure sensing elements including resistors R9, R10 in tension. As shown in Fig. 2 deflection of substrate 11 is measured by a change in value due to tension of the resistors formed by conductive tracks on substrate 11. Flow sensing means 13 includes heater 15 and temperature sensor 16. As shown in Fig. 2 flow rate is measured by detecting a measure of heat loss to the body of fluid being pumped adjacent the wet side of substrate 11. Substrate 11 includes microcontroller 14. Microcontroller 14 receives inputs from pressure sensing means 12 and flow sensing means 13 and is adapted to switch triac 17 controlling pump motor 18. Triac 17 is mounted in thermal communication with substrate 11 ensuring good dissipation of heat due to heat loss to the body of fluid being pumped adjacent the wet side of substrate 11. In some embodiments heater 15 may be dispensed with since its role may be performed by triac 17.

Fig. 3 shows a schematic circuit diagram of one form of sensor assembly according to the present invention. The sensor assembly includes microprocessor 30 which may comprise an ST6 family microprocessor manufactured by ST Microelectronics. The sensor assembly further includes temperature sensing means shown generally at 31 including fluid thermisters R16 and R18 and air thermister R38. Air thermister R38 is adapted to detect ambient temperature of air inside the enclosure that houses the electronics.

Microprocessor 30 is programmed to provide a measure of the temperature on the wet side of the substrate via thermister R16 and/or R18 and to also provide

a measure of the temperature on the dry side of the substrate via thermister R38. Microprocessor 30 is further programmed to compensate for anomalies caused by a temperature difference between the wet and dry sides of the substrate.

A temperature difference between the two sides of the substrate can have the effect of expanding one side, while contracting the other. This temperature difference can appear to microprocessor 30 as a change in pressure. In extreme cases, this can cause the controller to turn the pump on or off, independently of an actual pressure reading. In a 'mild' case, the accuracy of the cut in pressure may be affected. In combination with other factors, this temperature difference could potentially cause the controller (on a low pressure pump) to conclude that no water pressure is present and react to a 'loss of prime' situation by shutting down the pump unnecessarily.

The sensor assembly includes pressure sensing means shown generally at 32 and flow sensing means shown generally at 33. Pressure sensing means 32 includes a bridge circuit containing piezo resistors R9 and R10 and operational amplifier U1A. Flow sensing means 33 is based on thermal transfer or loss measurement principles as described herein and includes a bridge circuit containing thermisters R1 and R2 and operational amplifier U1B. The sensor assembly includes a triac drive for switching on a pump motor (not shown) and manual override / reset means shown generally at 36 and an LED alarm shown generally at 37.

The sensor assembly includes a heater for flow sensing means 33 designated by resistor R26 and a power supply shown generally at 38.

Microprocessor 30 may be programmed to capture or log operational data including key values of such data, over a period of time, such as the past 20 days. The logged data may include, the number of pump starts, operating voltage, etc. The logged data may serve as a diagnostic tool to facilitate fault location in the event of a service call or the like. For example, so called brown outs due to low supply voltages, particularly in remote installations, are a common cause of some failures.

Fig. 4 shows a cross section through the sensor housing including a seal assembly protecting the dry side 40 of sensor substrate 11. The seal assembly includes a high-pressure seal comprising a peripheral bead 41 interposed between the wet side 42 of substrate 11 and the peripheral inner edge 43 of the sensor housing adjacent flow sensing opening 50. Peripheral bead 41 is compressed by pressure applied to substrate 11 via closure element 44 associated with the housing.

A leak path 45 is provided to vent chamber 46, which vent chamber 46 is maintained at atmospheric pressure. Vent chamber 46 is insulated from the dry side 40 of sensor substrate 11 via a secondary seal which forms part of the seal assembly. The secondary seal comprises a peripheral bead 47 interposed between a peripheral edge associated with vent chamber 46 and closure element 44. Bead 47 is compressed by pressure applied via closure element

44. Closure element 44 is fixed to the main body of the sensor housing by screws or the like. Beads 41 and 47 are formed from an elastomeric material and connected by membrane 48 formed from a similar material. Membrane 48 provides an additional barrier to moisture reaching the dry side of substrate 11. Membrane 48 is substantially S-shaped in cross-section and includes recess 49 shaped to receive the peripheral edge of substrate 11.

Fig. 5 shows a view from the wet side of a practical embodiment of sensor substrate 11 mounted within a seal assembly 51.

Fig. 6 shows a view from the dry side of sensor substrate 11 mounted within the seal assembly 51. Fig. 6 clearly shows conductive tracks 60 and resistors 61 and other components printed onto substrate 11.

Fig. 7 shows electronic components associated with the sensor assembly mounted on the dry side of the sensor substrate 11.

Fig. 8 shows a view of the main body 80 of the housing for the sensor assembly together with its closure member 44.

Fig. 9 shows an underside view of closure member 44 including a projection 81 that is of similar contour to flow sensing opening 50 and is adapted to apply pressure to substrate 11 at least in the vicinity of the flow sensing opening 50.

Fig. 10 is a view of the main housing showing the flow sensing opening 50 nested within vent chamber 46. A peripheral recess 82 adapted to receive bead 41 of the seal assembly surrounds flow sensing opening 50.

Fig. 11 shows the sensor substrate 11 and seal assembly 51 mounted within vent chamber 46 of main body 80 of the housing.

Fig. 12 shows an underside view of the main body 80 of the housing with the closure member removed and the flow-sensing opening 50 clearly shown. A venturi device 83 is included in the vicinity of flow sensing opening 50. Venturi device 83 is shaped approximately like a human ear to accelerate the flow of pumped water in the vicinity of opening 50.

It will be appreciated that various alterations, modifications and / or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.